소아재활
발표일시 및 장소 : **10 월 27 일(토) 10:40-10:50 Room E(5F)**

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The effect of digital rehabilitation system with wearable IMU sensors in children with brain injury

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Purpose
This study investigated the effect of digital rehabilitation system with wearable multi-inertial measurement unit (IMU) sensors on upper limb functions in children with brain injury. Study design: A single blind randomized controlled trial, with an 8-weeks follow-up. Participants:Forty children (mean age 7.0 yrs) with cerebral palsy or static brain injury (6 months after the onset) were included at 3 rehabilitation institutions. Intervention: All participants received a daily rehabilitation treatment on upper limb for 60 minutes, 5 days per week for 4 weeks. The experimental group(n = 20) received 30 min of conventional occupational therapy(OT) and 30 min of therapy using the digital rehabilitation program with wearable IMU sensors. The control group(n = 20) received conventional OT alone for 60min per day for same duration. Training program using the digital rehabilitation system consisted of wrist and forearm articular movements: wrist flexion/extension, supination/pronation, ulnar/radial deviation correlated with visual stimuli using screen.

Outcome measure
Melbourne Assessment of Unilateral Upper Limb Function, version 2(MUUL-2) to measure the affected upper limb function; the Upper Limb Physician's Rating Scale(ULPRS) to measure each affected limb segment; the Pediatric Evaluation of Disability Inventory-computer adaptive test(PEDI-CAT) to assess activities of daily living capability. Assessments were performed by blinded assessors at baseline, after intervention, and 8 weeks after intervention. The percent score of MUUL-2 and scaled score of PEDI-CAT were used for analysis. Linear mixed analysis was used to assess differences in outcome measure over time and group.

Results
Thirty-nine subjects completed the intervention and no safety issues were reported. In the experimental group, upper limb functions measured by range, accuracy, and dexterity

domain of MUUL-2 were significantly improved after intervention($p<0.05$). Segmental movements in affected limb measured by wrist dorsiflexion and total score of ULPRS showed significant improvements in experimental group($p<0.05$). However, there were no significant differences in terms of interaction effect of group by time for any of the outcome measures of MUUL-2 and ULPRS. As for daily living capability, analysis of PEDI-CAT revealed group differences. The experimental group demonstrated significant improvements at 8-weeks follow up assessment in daily activity domain that were not observed in the control group.

Conclusion

Digital rehabilitation system with wearable IMU sensors is equally as effective as conventional OT in the training of upper limb function in children with brain injury. In addition, digital rehabilitation system remained superior for improving performances in daily activities. This new therapeutic approach using digital system may effectively complement standard rehabilitation by providing motivation and therapeutic support for children with brain injury.

Table 1. Characteristics of Participants

Characteristic	Intervention (n=20)	Control (n=19)	*P*-value†
Age (years)	7.10 ± 4.12 (3-16)	7.05 ± 3.29 (3-13)	0.749
Sex			
Male	10 (50.0%)	14 (73.7%)	0.191
Female	10 (50.0%)	5 (26.3%)	
MACS			
I-II	10 (50.0%)	8 (42.1%)	0.751
III-IV	10 (50.0%)	11 (57.9%)	
HFCS (study limb)			
4	3 (15.0%)	3 (15.8%)	
5	7 (35.0%)	5 (26.3%)	0.892
6	8 (40.0%)	10 (52.6%)	
7	2 (10.0%)	1 (5.3%)	
Involved side			
Hemiplegia/ Triplegia	9 (45.0%)	9 (47.4%)	>0.999
Quadriplegia	11 (55.0%)	10 (52.6%)	

Values are expressed as number (%) or mean ± standard deviation (range)
MACS, Manual Ability Classification System; HFCS, House Functional Classification System
† P-values were calculated by Mann-Whitney test, Chi-square tests, or Fisher's exact test.

Table 2. Descriptive Statistics of Outcome Measures at Baseline, After Intervention, and at 8 Weeks Follow-Up and Statistical Comparison

		Baseline	Post-intervention	8-week Follow-up	*P*-value	
					Time	Time x Group
Melbourne Assessment-II						
Range	Rapael	71.49 (22.06)	**75.64**[†] (20.04)	**74.82**[†] (21.62)	**0.013**[*]	0.488
	Control	66.47 (25.23)	69.40 (23.32)	67.25 (22.77)	0.100	
Accuracy	Rapael	84.40 (19.93)	**89.00**[†] (16.10)	87.40 (19.04)	**0.031**[*]	0.558
	Control	79.37 (26.68)	**85.26**[†] (21.67)	**85.26**[†] (23.48)	**0.030**[*]	
Dexterity	Rapael	63.02 (23.83)	**68.56**[†] (23.52)	**69.69**[†] (25.02)	**0.003**[*]	0.166
	Control	62.00 (24.26)	63.14 (23.28)	66.76 (24.39)	0.064	
Fluency	Rapael	62.14 (23.71)	64.52 (21.88)	64.29 (20.41)	0.457	0.715
	Control	52.88 (23.75)	55.39 (24.55)	56.39 (23.82)	0.101	
ULPRS						
Active elbow extension	Rapael	1.70 (0.66)	1.85 (0.37)	1.85 (0.37)	0.212	0.552
	Control	1.63 (0.68)	1.68 (0.67)	1.68 (0.67)	0.577	
Active supination in extension	Rapael	2.60 (0.82)	2.70 (0.73)	2.70 (0.73)	0.162	0.553
	Control	2.37 (0.96)	2.47 (0.91)	2.53 (0.91)	0.520	
Active supination in flexion	Rapael	2.70 (0.57)	2.80 (0.52)	2.80 (0.52)	0.162	0.352
	Control	2.47 (0.84)	2.68 (0.75)	2.68 (0.75)	**0.042**[*]	
Active wrist dorsiflexion	Rapael	2.70 (0.57)	2.80 (0.41)	2.77 (0.47)	0.133	0.429
	Control	2.63 (0.83)	2.84 (0.38)	2.84 (0.38)	0.085	
Wrist dorsiflexion	Rapael	1.00 (0.80)	1.20 (0.83)	**1.35**[†] (0.81)	**0.049**[*]	0.796
	Control	1.26 (0.81)	1.37 (0.68)	1.47 (0.70)	0.512	
Finger opening	Rapael	1.60 (0.68)	1.70 (0.66)	1.65 (0.67)	0.214	0.377
	Control	1.74 (0.56)	1.84 (0.50)	1.89 (0.32)	0.213	
Thumb in palm	Rapael	3.20 (1.32)	3.35 (1.14)	3.45 (1.10)	0.152	0.821
	Control	3.16 (1.17)	3.26 (1.15)	3.32 (1.16)	0.213	
Associated increase in muscle tone	Rapael	1.40 (0.82)	1.50 (0.89)	1.55 (0.83)	0.214	0.345
	Control	1.26 (0.73)	1.26 (0.73)	1.37 (0.83)	0.330	
Two-handed function	Rapael	1.50 (0.69)	1.55 (0.69)	1.55 (0.69)	0.291	0.377
	Control	1.26 (0.93)	1.26 (0.93)	1.32 (0.95)	0.330	
Total	Rapael	18.40 (4.75)	**19.45**[†] (4.54)	**19.70**[†] (4.56)	**0.007**[*]	0.736
	Control	17.79 (5.63)	18.68 (5.00)	**19.11**[†] (4.99)	**0.033**[*]	
PEDI-CAT						
Daily activity	Rapael	50.20 (3.16)	50.60 (2.84)	**51.70**[†‡] (3.50)	**0.002**[*]	**0.030**[*]
	Control	48.58 (4.86)	49.00 (4.51)	49.05 (4.87)	0.335	
Mobility	Rapael	58.30 (5.78)	58.85 (5.37)	59.20 (4.87)	0.386	0.592
	Control	56.53 (7.88)	56.42 (7.27)	56.68 (6.78)	0.827	
Social cognitive	Rapael	64.50 (3.43)	64.80 (3.38)	65.70 (3.74)	<0.001	0.103
	Control	63.05 (3.26)	63.32 (3.43)	63.53 (3.37)	0.229	
Responsibility	Rapael	44.70 (4.43)	45.05 (4.11)	45.50 (3.47)	0.407	0.454
	Control	41.90 (6.34)	43.32 (5.09)	44.16 (4.81)	0.064	

ULPRS, upper limb physician's rating scale; PEDI-CAT, pediatric evaluation of disability inventory-computer adaptive test

[*] $p < 0.05$ by linear mixed model

[†] $p < 0.05$ by Bonferroni adjusted post hoc analysis, compared with baseline assessment

[‡] $p < 0.05$ by Bonferroni adjusted post hoc analysis, compared with post-intervention assessment